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Treatment of Ruptured Abdominal Aortic Aneurysm, a Permanent Challenge or a Waste of Resources? Prediction of Outcome Using a Multi-organ-dysfunction Score

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Objectives: *in a retrospective study, attempts have been made to identify individual organ-dysfunction risk profiles influencing the outcome after surgery for ruptured abdominal aortic aneurysms.*
Methods: *out of 235 patients undergoing graft replacement for abdominal aortic aneurysms, 57 (53 men, four women, mean age 72 years [S.D. 8.8]) were treated for ruptured aneurysms in a 3-year period. Forty-eight preoperative, 13 intraoperative and 34 postoperative variables were evaluated statistically. A simple multi-organ dysfunction (MOD) score was adopted.*
Results: *the perioperative mortality was 32%. Three patients died intraoperatively, four within 48 h and 11 died later. A significant influence for pre-existing risk factors was identified only for cardiovascular diseases. Multiple linear-regression analysis indicated that a haemoglobin <90 g/l, systolic blood pressure <80 mmHg and ECG signs of ischaemia at admission were highly significant risk factors. The cause of death for patients, who died more than 48 h postoperatively, was mainly MOD. All patients with a MOD score ≥4 died (n=7). These patients required 27% of the intensive-care unit (ICU) days of all patients and 72% of the ICU days of the non-survivors.*
Conclusion: *patients with ruptured aortic aneurysms from treatment should not be excluded. However, a physiological scoring system after 48 h appears justifiable in order to decide on the appropriateness of continual ICU support.*

Key Words: Ruptured abdominal aortic aneurysm; Multi-organ-failure score; Prognosis; Mortality; Complications.

Introduction

Despite a continuous increase in the number of elective operations on abdominal aortic aneurysms (AAAs), there is at present no decrease in the incidence of ruptured abdominal aortic aneurysms (RAAAs).[1] The number of AAAs treated surgically is evidently too small to reduce the risk of rupture, but the incidence is rising substantially in Western industrialised countries.[2–5] For ethical and moral reasons, it seems difficult to withhold treatment in the emergency situation. However, such questions are often raised during prolonged treatment on the intensive-care unit. Many attempts have been made to establish individual risk profiles for surgical measures, to identify specific risk groups and to infer prognostic factors, especially for the ruptured aortic aneurysm.[6–14] Use of preoperative, intraoperative and early postoperative parameters to generate prognostic scores seems an attractive notion, but has encountered limitations in the past.[12,13] Today, it is essential to consider the possibility of saving resources that could be more appropriately used for other cases with better prospects of success.

Previous retrospective investigations were mostly carried out over a long time period and the method of treatment, anaesthesia and intensive care were therefore heterogenous. We used a shorter period of observation (36 months) with a standardised and therefore largely homogenous surgical, anaesthesiological and intensive-care procedure, in an attempt to diminish these methodological errors.

Materials and Methods

From a total of 235 patients who had received an abdominal aortic aneurysm repair, during a three-year period (October 1995 to October 1998), 57 cases with RAAA (53 men, four women, average age 72 years

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[S.D. 8.8]) were identified. Cases with ruptured thoracoabdominal and iliac artery aneurysm and patients in whom an operation was not carried out primarily, or had been refused by the patient, were excluded. In nine cases (16%) the AAA had been previously known but was not treated mainly at the request of the patient or because the family doctor had advised against treatment. The transverse diameter (estimated intraoperatively or derived from available CT scans) of the aneurysm in these patients averaged 5.4 cm (4–7 cm) at diagnosis. In 53 cases there was a retroperitoneal rupture (mostly on the left side). In one case an aortocaval fistula was found, and in three cases intraperitoneal rupture had occurred. The study period was deliverately kept short in order to minimise methodological errors with exclusive responsibility of two surgeons (standardised surgical procedure) and routine anaesthesiological and intensive-care management.

Surgical technique

The approach was routinely performed via median laparotomy. In 18 cases (32%) with extensive retroperitoneal haematoma and extreme hypotension, subphrenic clamping of the aorta was performed primarily. After volume substitution and stabilisation of blood pressure, the aortic clamp was moved to the aneurysmal neck (infrarenal or suprarenal), so that visceral and renal perfusion could be restored after 5–10 min. When the anastomosis had to be performed with suprarenal cross-clamping (five cases), the kidneys were cooled by flush perfusion (4°C Ringer's solution, addition of PGE_1 + heparin) while the proximal anastomosis was made.[15] Whenever possible, a tube graft was used. However, a bifurcation graft had to be implanted in 39% of patients with concomitant dilatation of the iliac arteries.

Definition of organ failure

Forty-eight preoperative, 13 intraoperative and 34 postoperative variables were evaluated. From Meesters *et al.*[7] a simpler definition of organ failure was adopted compared to that employed in other multi-organ-dysfunction (MOD) scores[16] in order to enable a comparison of the results and conclusions (Table 1).

For the 50 patients who were still alive 48 h after the operation, the multiple-organ-failure classification (MOD score) was carried out according to Meesters *et al.*[7] One point is allotted for failure of one organ system (maximum MOD score of 5) for cardiovascular, pulmonary, renal and hepatic failure as well as failure of the haematological system. Since the Quick-value is used in Switzerland instead of the prothrombin time in seconds vs. the control value, a prothrombin time of >4 was replaced by a corresponding Quick-value $\leq$60% to define liver failure. A horizontal or lowered ST segment of >0.1 mV or an associated alteration in the T-wave in the admission ECG was evaluated as an ECG sign of ischaemia.

Statistical analysis

The statistical analysis was carried out with an IBM-compatible personal computer by means of STATA (statistics/data analysis, Stata Corporation, Texas, U.S.A.). The exact Fisher test or the χ^2 test were used for univariate analysis of categorical data. The Student's *t*-test for unequal variances (unpaired random samples) was used for parametric data, and the Mann–Whitney *U*-test for non-parametric data. The continuous variables were subdivided into categories which were investigated for significant differences in the mortality rate. Significant parameters on univariate analysis were checked by linear regression in a backwards and forwards elimination procedure. The significance level laid down was $p<0.05$.

Results

A total of 18 patients (32%) died perioperatively (hospital mortality), three died intraoperatively (5%), four died within 48 h after the operation (7%) and 11 (9%) died later than 48 h after the operation. The 30-day mortality was 30%. From the beginning of pain up to operation (cutaneous incision), a median of 10 h elapsed (range 1.6–504 h). Direct admission to our hospital or prior investigation elsewhere involving transport, clinical assessment or further investigation did not have any significant effect with regard to survival, although the time difference between admission to a peripheral hospital/skin incision (median 3.2 h, range 1–144 h) and direct admission to our hospital/skin incision (median 77.5 min, range 15–280 min) differed significantly ($p=0.0003$). Pre-existing risk factors and concomitant diseases were

Table 1. Definition of organ system failure according to Meesters *et al.*[7]: every organ system that failed was scored with 1 point. Accordingly, for each patient an organ-failure score from 0 to 5 could be recorded (definition slightly modified: instead of prothrombin time >4 s vs. control, spontaneous Quick-value ≤60% was measured for hepatic failure).

Cardiovascular failure	One or more of the following: systolic blood pressure <100 mmHg and/or dependence on inotropic treatment* ventricular tachycardia and/or ventricular fibrillation bradycardia <54 beats/min
Respiratory failure	Dependence on ventilator at 48 h
Renal failure	One or more of the following: serum urea >36 mmol/l serum creatinine >300 μmol/l urine output <150 ml over past 8 h
Haematological failure	One or more of the following: thrombocytopenia $<60 \times 10^9$/l platelet transfusion in the past 8 h** white cell count ≤1000/mm^3 haematocrit ≤20%
Hepatic failure	One or more of the following: Quick-value ≤60% (if the patient was not treated with coumadine derivates) total serum bilirubin >200 μmol/l

* Inotropic treatment started with systolic blood pressure <100 mmHg.
** Platelet transfusion was started with thrombocytes $<60 \times 10^9$/l and evidence of bleeding.

Table 2. Prevalence and significance of risk factors and concomitant diseases.

Risk factors, concomitant diseases	Survived *n* (%)	Deceased *n* (%)	*p*
Smoking	25 (64.1)	7 (38.9)	0.075 (n.s.)
COPD	18 (46.2)	4 (22.2)	0.084 (n.s.)
Hypertension	27 (69.2)	8 (44.4)	0.074 (n.s.)
Hypercholesterolaemia	8 (20.5)	2 (11.1)	0.386 (n.s.)
Diabetes	8 (20.5)	4 (22.2)	0.883 (n.s.)
Renal insufficiency, haemodialysis	3 (7.7)	1 (5.6)	0.769 (n.s.)
Myocardial insufficiency, infarction, reduced EF	7 (17.9)	8 (44.4)	0.035
Coronary heart disease	11 (28.2)	10 (55.6)	0.047
Renal artery stenosis	2 (5.1)	0 (0)	1.000 (n.s.)
Carotid artery stenosis	1 (2.6)	1 (5.6)	0.568 (n.s.)
Peripheral arterial disease	8 (20.5)	3 (16.7)	0.732 (n.s.)
Additional aneurysms, other locations	5 (12.8)	1 (5.6)	0.406 (n.s.)
Malignancy	1 (2.6)	0 (0)	1.000 (n.s.)
Total	39	18	

n.s. = Not significant.

evaluated with regard to survival (Table 2). Significant differences between surviving and deceased patients were found only with regard to pre-existing myocardial infarction/heart failure/reduced ejection fraction (EF) and coronary heart disease (CHD).

In 33 patients (61%), the aorta was replaced by a tube prosthesis, and in 21 cases (39%) with a bifurcation graft. The three patients who died intraoperatively were not evaluated. The bifurcation graft was usually anastomosed intra-abdominally but in two cases an aortobifemoral bypass was performed (both patients died). A significant difference could not be found between the surviving and deceased patients with regard to aortic cross-clamping time ($p = 0.19$), but the overall duration of operation of the deceased patients (median 180 min) was significantly longer than that of the surviving patients (median 170 min) ($p = 0.044$). In the patients who died perioperatively (patients who died intraoperatively were not evaluated), the amount of blood and plasma constituents given was significantly greater, both intraoperatively and postoperatively (Table 3).

Duration of stay in hospital, length of time spent on the intensive-care unit and intensive-surveillance ward were also evaluated. On average, the surviving patients spent a median of 19 days (range 10–97 days) and those who died more than 48 h postoperatively spent a median of 17 days (range 9–36 days) in hospital. Patients who died later than 48 h after the operation remained in the intensive-care unit for significantly longer (median 17 days) than the surviving patients (median 3 days) ($p = 0.0005$).

Table 3. Amount of intra- and postoperative transfusion of packed red blood cells and blood derivates (patients deceased intraoperatively not considered).

	Survivors			Deceased			p
	Mean	Median	Range	Mean	Median	Range	
Intraoperative							
Blood transfusion (units)	11.3	10	0–39	23.5	18	2–50	0.0019
FFP (units)	8.5	6	0–34	17.3	16	0–38	0.0300
Platelet transfusion (units)	1.9	0	0–13	4.1	2	0–12	0.0429
Postoperative							
Blood transfusion (units)	3.9	1	0–31	12.6	6	0–31	0.0093
FFP (units)	2	0	0–18	7	2	0–26	0.0018
Platelet transfusion (units)	0.9	0	0–13	5	0	0–19	0.0331
Total							
Blood transfusion (units)	15.7	12	0–63	36.5	36	5–72	0.0002
FFP (units)	11	8	0–46	24.5	20	0–64	0.0092
Platelet transfusion (units)	3	0	0–19	10.1	8	0–30	0.0108

Table 4. Incidence and significance of postoperative complications, table divided into complications, which may be influenced by technique and experience, and predominantly shock-related organ failure. (MOF = multi-organ-failure, intraop. deceased patients not considered.)

Early complications	Survived: $n=39$ n (%)	Deceased: $n=15$ n (%)	p
Trashfoot	2 (5.1)	0 (0)	1.000 (n.s.)
Graft infection	1 (2.6)	0 (0)	1.000 (n.s.)
Sepsis	1 (2.6)	6 (40)	<0.001
Bleeding complication	5 (12.8)	6 (40)	0.055 (n.s.)
Renal insufficiency –	9 (23.1)	10 (66.7)	0.003
haemodialysis – filtration	7 (17.9)	8 (53.3)	0.009
Colon ischaemia	5 (12.8)	5 (33.3)	0.082 (n.s.)
Total	13 (33.3)	12 (80)	0.002
Organ failure	**Survived: $n=39$ n (%)**	**Deceased: $n=15$ n (%)**	**p**
MOF	2 (5.1)	15 (100)	<0.001
Cardiovascular insufficiency	9 (23.1)	13 (86.7)	<0.001
Pulmonary insufficiency	12 (30.8)	15 (100)	<0.001
Hepatic insufficiency	4 (10.3)	9 (60)	<0.001
Total	19 (48.7)	15 (100)	<0.001

n.s. = Not significant.

The early complications are listed in Table 4. Eleven patients (20%) had no complications, whereas 31 patients (57%) had more than one complication. Reoperations were required in 15 patients, mainly for bleeding,[8] and several reinterventions were necessary in some cases. Some of these were planned as a second-look operation. Four patients required colonic resection for ischaemia. One patient developed graft infection after 5 weeks and the prosthesis was replaced with a homologous transplant.

MOD score

Forty-eight hours after the primary operation, 50 patients were still alive, each of whom underwent a maximum (best possible) treatment. All patients with an MOD score of $=4$ died ($n=7$). On the other hand, half of the four patients with a score of 3 survived (Table 5). Altogether, the 57 patients spent a total of 487 days on the intensive-care unit. However, the seven patients with a MOD score of ≥ 4, of whom none survived, required 129 days (26.5% of the total intensive-care bed-days). Univariate analysis of the parameters measured on admission showed that the haemoglobin, haematocrit, thrombocytes, Quick-value, blood pressure, unstable circulation, anuria, history of loss of consciousness, ECG signs of ischaemia and cardiac resuscitation were significantly correlated with death (Table 6). All patients requiring resuscitation preoperatively died. On the other hand, other variables such as age, urea, creatinine, blood or

Table 5. MOD score after 48 h postoperative, mortality and duration of stay at the ICU of 50 patients with maximal intensive care therapy.

MOD score	Mortality rate (%)	Survivors – total of days at the ICU				Deceased – total of days at the ICU			
		days	(patients)	median	mean (range)	days	(patients)	median	mean (range)
0	0	86	(22)	3	3.9 (1–17)	0	(0)	0	0 (0)
1	16.7	17	(5)	3	3.4 (1– 8)	10	(1)	10	10 (10–10)
2	9.1	138	(10)	8.5	13.8 (1–33)	15	(1)	15	15 (15–15)
3	50	61	(2)	30.5	30.5 (11–50)	27	(2)	13.5	13.5 (8–19)
4	100	0	(0)	0	0 (0)	97	(5)	21	19.4 (9–26)
5	100	0	(0)	0	0 (0)	32	(2)	16	16 (13–19)

Table 6. Significance of quantitative and categorised parameters, measured at admittance (preoperatively).

Parameter	Survivors			Deceased			*p*
	mean	95% CI	*n*	mean	95% CI	*n*	
Age	70.8	68.1– 73.6	39	74.1	69.5– 78.8	18	0.2168 (n.s.)
Haemoglobin (g/l)	122.7	114.0–131.5	39	91.8	74.4–109.3	18	0.0027
Haematocrit (%)	36.7	34.1– 39.3	36	29.4	23.9– 34.8	16	0.0173
Thrombocytes (g/l)	208.2	181.5–234.9	37	138.5	100.7–176.3	18	0.0034
Quick-value (%)	77.5	67.9– 87.1	34	51.9	35.8– 68.0	16	0.0078
Serum creatinine (μmol/l)	129.0	110.8–147.2	37	153.9	106.1–201.6	16	0.1780 (n.s.)
Serum urea (mmol/l)	9.9	7.6– 12.1	26	10.5	5.0– 15.9	12	0.8228 (n.s.)
Systolic blood pressure (mmHg)	121.4	109.9–132.9	34	89.5	74.9–104.2	17	0.0010

Parameter	Survivors *n* (%)	Deceased *n* (%)	*p*
Severe hypotension	11/39 (28.2)	14/18 (77.8)	<0.001
Anuria	1/39 (2.6)	4/18 (22.2)	0.015
History of collapse	11/39 (28.2)	10/18 (55.6)	0.047
Unconsciousness at admission	2/39 (5.1)	8/18 (44.4)	<0.001
ECG ischaemia	1/34 (2.9)	8/17 (47.1)	<0.001
Intubated at admission	3/39 (7.7)	5/18 (27.8)	0.042
Resuscitation required	0/39 (0)	6/18 (33.3)	0.001
Blood transfusion required	5/39 (12.8)	2/18 (11.1)	0.855 (n.s.)
FFP required	2/39 (5.1)	0/18 (0)	1.0 (n.s.)
Blood transfusion and FFP required	2/39 (5.1)	1/18 (5.6)	0.946 (n.s.)

n.s. = Not significant.

plasma administration and intubation did not show any significant differences.

The continuous variables that were significant were subdivided into categories. A haemoglobin <90 g/l (mortality 82%), haematocrit <30% (mortality 57%), thrombocytes $<130\times10^9$/l (mortality 73%), spontaneous Quick-value <70% (mortality after exclusion of anticoagulated patients 90%) and blood pressure <80 mmHg (mortality 82%) were each associated with a very much higher mortality rate compared to other categories. An analysis of the significant variables on univariate analysis by multiple linear regression, using the backwards and forwards elimination method, showed that haemoglobin <90 g/l, systolic blood pressure <80 mmHg and ECG signs of ischaemia were highly significant risk factors for survival (Table 7). Using the same weighting, the cumulative effect of these highly significant risk factors showed that presence of two of these risk factors was associated with a mortality of 100% (Table 8).

Analysis of the cause of death for the patient group ($n = 15$) that died postoperatively showed that, apart from one patient who died of massive pulmonary embolism and one patient who died of electromechanical dissociation, multi-organ failure was the leading cause of death in 93%, whereas intraoperative death was attributable to DIC (disseminated intravascular coagulation) in two cases and myocardial failure in one case.

Discussion

The overall mortality for ruptured abdominal aortic aneurysms varies between 85% and 95%.[17,18] The ma-

Table 7. Significance of, with perioperative mortality associated, three independent variables – recorded at admittance – in a multivariate model.

Variables	Coef.	95% CI	p
Systolic blood pressure <80 mmHg	0.443	0.211–0.676	0.0003
Haemoglobin <90 g/l	0.389	0.145–0.632	0.0023
ECG ischaemia	0.381	0.113–0.649	0.0062

Table 8. Perioperative mortality related to the absence or presence of one or more preoperative independent risk factors shown in Table 7.

Number of risk factors	Patients n	Deceased n	%
0	37	3	8.1
1	11	6	54.5
2	7	7	100
3	2	2	100

jority of patients die without ever reaching hospital and, of those who reached hospital alive, between 30% and 70% survive. A further reduction of the mortality has not been achieved in vascular surgery centres despite increasing experience, standardisation of the surgical technique and major advances in anaesthesia and intensive-care medicine. In contrast to elective aneurysm surgery, the perioperative mortality evidently does not depend so much on experience in vascular surgery[19,20] but is much more dependent on factors such as preoperative condition and organ damage due to shock, which induce multi-organ failure. These cannot be influenced or only influenced to a small extent.[7,10,21–23] Multi-organ failure in patients who died more than 48 h after the operation was the cause of death in more than 90% of our patients.

In times of restricted resources and development of new, but costly, methods of treatment, the cost–benefit question has also increasingly become the focus of health policy in relation to elaborate methods of treatment. The perioperative costs for a patient with RAAA in the U.S.A. average $40 000 ($4473–$284 374) with age-dependent annual postoperative costs between $3953 and $10 557.[24–26] Similar costs are likely in Europe, which means that the cost of a ruptured aneurysm exceeds those of an elective operation by a factor of 5–10. The majority of the excessive costs of treating ruptured aneurysms are caused by the stay in intensive care. We were able to demonstrate as clearly as Meesters *et al.*[7] that more than 48 h after the operation a substantial proportion of all intensive-care days (approximately 40%) was used to treat the relatively few patients who then did not survive. Considering all intensive-care days, 25% of all costs were not spent appropriately (score $\geq$IV).

It seems appropriate, therefore, to use a simple multi-organ failure score as described by Meesters *et al.*,[7] who were able to demonstrate that none of the patients with the score ≥ 3 survived. Since there was no "false-positive survivor" at a score of ≥ 3, the logical conclusion would be that treatment should no longer be continued for patients in whom this score is reached. However, in contrast to the study of Meesters *et al.*, who reported a 100% death rate for patients with a score of 3, only 50% of our patients with a score of 3 using the same classification died, while those with a score of ≥ 4 all died. These data document the complexity of the application and transferability of such scores. A score threshold of ≥ 3 was also rejected by Meesters *et al.*, because the limits were too narrow and larger numbers of cases were required. Nevertheless, we consider use of the MOD score system appropriate, since a decision does not have to be made preoperatively with insufficient information, as the appraisal is only made >48 h after the operation. Continuation or termination of intensive therapy can then be justified on the basis of the known facts.

Amongst the singularly evaluated anamnestic data such as age, renal failure, stroke, etc., a (significant) prognostic importance could only be ascribed to cardiovascular factors. However, in the opinion of ourselves and others, they do not allow a definitive prognosis with regard to refusal of surgical therapy.[23] Like other investigators,[27] we were able to document a greater prognostic importance for factors such as haemoglobin ≤ 9 g/l, systolic blood pressure <80 mmHg or ECG signs of ischaemia. A combination of these factors further reduced the prospects of survival.[26,27] Patients with two of the risk factors determined in this way had a mortality of 100%. However, because of the small number of cases in our study, we feel it would be inappropriate to deny these patients treatment on admission.

As a result of our study, we now classify patients with RAAA after 48 h using the MOD scoring system. The decision to terminate treatment in patients with a score 5 are not controversial. Nevertheless, at present we hesitate to stop treatment in patients with a score = 4 pending the results of a prospective trial, utilising the same scoring system.

References

1 Johansson G, Swedenborg J. Little impact of elective surgery on the incidence and mortality of ruptured aortic aneurysms. *Eur J Vasc Endovasc Surg* 1994; **8**: 489–493.
2 Naylor AR, Webb J, Fowkes FGR, Ruckley CV. Trends in

abdominal aortic aneurysm surgery in Scotland (1971–1984). *Eur J Vasc Surg* 1988; **2**: 217–221.
3 Castleden WM, Mercer JC. Abdominal aortic aneurysms in western Australia: descriptive epidemiology and patterns of rupture. *Br J Surg* 1985; **72**: 109–112.
4 Melton LJ, Bickerstaff LK, Hollier LH *et al.* Changing incidence of abdominal aortic aneurysms: a population-based study. *Am J Epidemiol* 1984; **120**: 379–386.
5 Kniemeyer HW, Edelmann M, Reber PU, Hakki H. Inzidenz, Prävalenz und Spontanverlauf abdomineller Aortenaneurysmen – Wann soll ein Aneurysma operiert werden? *Münch Med Wschr* 1999; **141**: 36–40.
6 DeDombal FT, Clamp SE, Softley A, Unwin BJ, Staniland JR. Prediction of individual patient prognosis: value of computer-aided systems. *Med Decis Making* 1986; **6**: 18–22.
7 Meesters RCT, Van de Graff Y, Vos A, Eikelboom BC. Ruptured abdominal aortic aneurysm: early postoperative prediction of mortality using an organ system failure score. *Br J Surg* 1994; **81**: 512–516.
8 Lazarides MK, Arvanitis DP, Drista H, Staramos DN, Dayantas JN. POSSUM and APACHE II scores do not predict the outcome of ruptured infrarenal aortic aneurysms. *Ann Vasc Surg* 1997; **11**: 155–158.
9 Soong DV, Halliday MI, Hood JM, Rowlands BJ, Barros d'Sa AA. The use of tonometry to predict mortality in patients undergoing abdominal aortic aneurysm repair. *Eur J Vasc Endovasc Surg* 1998; **15**: 24–28.
10 Maziak DE, Lindsay TF, Marshall JC, Walker PM. The impact of multiple organ dysfunction on mortality following ruptured abdominal aortic aneurysm repair. *Ann Vasc Surg* 1998; **12**: 93–100.
11 Bauer EP, Redaelli C, von Segesser LK, Turina MI. Ruptured abdominal aortic aneurysms: predictors for early complications and death. *Surgery* 1993; **114**: 31–35.
12 Wolters U, Wolf T, Stutzer H, Schroder T, Pichlmaier H. Risk factors, complications, and outcome in surgery: a multivariate analysis. *Eur J Surg* 1997; **163**: 563–568.
13 Troeng T. Is it possible to predict outcome in an individual patient? *Ann Chir Gynaecol* 1998; **87**: 126–127.
14 Farooq MM, Freischlag JA, Seabrook GR *et al.* Effect of the duration of symptoms, transport time, and length of emergency room stay on morbidity and mortality in patients with ruptured abdominal aortic aneurysms. *Surgery* 1996; **119**: 9–14.
15 Torsello G, Schrör K, Szabo Z *et al.* Effects of prostaglandin E1 (PGE1) on experimental renal failure. *Eur J Vasc Surg* 1989; **3**: 5–13.
16 Marshall JC, Sibbald WJ, Cook DA *et al.* The multiple organ dysfunction (MOD) score: a reliable descriptor of a complex clinical outcome. *Crit Care Med* 1995; **23**: 1638–1652.
17 Johansson G, Swedenborg J. Ruptured abdominal aortic aneurysms: a study of incidence and mortality. *Br J Surg* 1986; **73**: 101.
18 Budd JS, Finch DRA, Carter PG. A study of the mortality from ruptured abdominal aortic aneurysms in a district community. *Eur J Vasc Surg* 1989; **3**: 351.
19 Kantonen I, Lepäntalo M, Salenius J-P *et al.* Mortality in abdominal aortic aneurysm surgery – the effect of hospital volume, patient mix and surgeon's case load. *Eur J Vasc Endovasc Surg* 1997; **14**: 375–379.
20 Glovitzki P, Pairolero PC, Mucha Jr P *et al.* Ruptured abdominal aortic aneurysms: repair should not be denied. *J Vasc Surg* 1992; **15**: 851–859.
21 Peerless JR, Alexander JJ, Pinchak AC, Piotrowski JJ, Malangoni MA. Oxygen delivery is an important predictor of outcome in patients with ruptured abdominal aortic aneurysms. *Ann Surg* 1998; **227**: 726–734.
22 Nachbur B, Gut A, Sigrist S. Prognostic factors in the surgical treatment of aorto-iliac aneurysmal disease. *J Cardiovasc Surg* 1987; **28**: 469–478.
23 Panneton JM, Lassonde J, Laurendeau F. Ruptured abdominal aortic aneurysm: impact of comorbidity and postoperative complications on outcome. *Ann Vasc Surg* 1995; **9**: 535–541.
24 Breckwoldt WL, Mackey WC, O'Donnell TF. The economic implications of high-risk abdominal aortic aneurysms. *J Vasc Surg* 1991; **13**: 798–804.
25 Seiwert AJ, Elmore JR, Youkey JR, Franklin DP. Ruptured abdominal aortic aneurysm repair: the financial analysis. *Am J Surg* 1995; **170**: 91–96.
26 Marry MC, Merriman B, Wiley M *et al.* Ruptured abdominal aortic aneurysm – can treatment costs and outcomes be predicted by using clinical or physiological parameters? *Eur J Vasc Endovasc Surg* 1997; **14**: 487–491.
27 Hardman DTA, Fisher CM, Patel MI *et al.* Ruptured abdominal aortic aneurysms: who should be offered surgery? *J Vasc Surg* 1996; **23**: 123–129.

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